

Supplementary from Davidson et al “Diet-induced changes to host gut microbiota are linked to foraging innovation in a wild bird”.

Table S1. Estimated nutritional content of food types provided in dietary treatments. Percentages of protein, fat and fibre content attained from online resources.

Food	Protein	Fat	Fibre
mealworm larvae	18.70%	13.40%	2.50%
waxworm larvae	14.10%	24.90%	3.40%
peanuts	25.80%	49.20%	8.50%
sunflower hearts	18.33%	46.67%	10%

Table S2. GLMM outputs from models testing dietary effects on problem solving performance and gut microbiome

Model	subjects	total observations	Fixed effects	$\beta \pm SE$	z/t	p	
Diet on PSP	36	71	intercept	0.88±0.52	-1.70	0.09	
	Minimal model	36	71	seed diet	1.43±0.66	2.20	0.03
		36	71	age (adult)	1.32±0.68	-1.93	0.053
	dropped terms	36	71	experiment day	1.23±0.64	-1.93	0.054
		36	71	sex (male)	0.20±0.68	-0.30	0.76
		36	71	habitat	0.06±0.59	-0.10	0.92
		36	71	diet*habitat	1.09±1.22	0.89	0.37
		36	71	diet*experiment day	17.6±1445	0.01	0.99
Diet on Chao1	36	61	intercept	18.5±0.70	26.54	0.00	
	Minimal model	36	61	insect diet	3.44±1.37	-2.51	0.02
		36	61	seed diet	0.09±1.30	0.07	0.94
	dropped terms	36	61	habitat (urban)	0.67±1.90	0.61	0.55
		36	61	sex (male)	0.45±1.08	-0.41	0.68
		36	61	age (adult)	0.34±1.10	-0.31	0.75
	36	61	diet*habitat	3.07±2.11	1.45	0.16	
Diet on Shannon's index	36	61	intercept	2.93±0.20	14.75	0.00	
	Minimal model	36	61	insect diet	0.75±0.37	-2.02	0.06
		36	61	seed diet	0.01±0.35	0.01	0.99
	dropped terms	36	61	habitat (urban)	0.14±0.33	-0.42	0.68
		36	61	sex (male)	0.22±0.32	0.67	0.51
		36	61	age (adult)	0.01±0.33	0.02	0.98
	36	61	diet*habitat	0.92±0.64	1.44	0.16	
Diet on observed species	36	61	intercept	5.5±0.01	58.80	0.00	
	Minimal model	36	61	insect diet	0.32±0.19	-1.74	0.095
		36	61	seed diet	0.08±0.18	0.43	0.67

dropped terms	36	61	habitat (urban)	0.17±0.14	1.19	0.24
	36	61	sex (male)	0.01±0.14	-0.10	0.92
	36	61	age (adult)	0.07±0.15	-0.49	0.62
	36	61	diet*habitat	0.42±0.28	1.52	0.14
Diet on Proteobacteria	36	61	intercept	0.42±0.43	-0.97	0.33
Minimal model	36	61	insect diet	1.8±0.87	2.02	0.04
	36	61	seed diet	0.19±0.66	-0.28	0.78
	36	61	age (mature)	1.05±0.57	1.84	0.07
dropped terms	36	61	sex (male)	-0.02±0.6	-0.03	0.98
	36	61	habitat (urban)	0.35±0.57	0.61	0.54
	36	61	diet*habitat	0.29±1.11	-0.26	0.80
Diet on Bacteroidetes			intercept	6.23±0.30	-20.60	0.00
Minimal model	36	61	insect diet	1.32±0.59	2.25	0.03
	36	61	seed diet	0.56±0.56	1.01	0.32
	36	61	habitat (urban)	0.82±0.46	1.80	0.08
dropped terms	36	61	sex (male)	0.58±0.45	1.29	0.20
	36	61	age (adult)	0.09±0.47	0.20	0.84
	36	61	diet*habitat	1.54±0.92	1.68	1.00
Diet on Firmicutes			intercept	3.00±0.23	-12.93	0.00
minimal model	36	61	age (adult)	0.63±0.34	-1.85	0.07
	36	61	insect diet	0.39±0.42	-0.92	0.37
dropped terms	36	61	seed diet	0.15±0.40	0.39	0.70
	36	61	habitat (urban)	0.07±0.35	0.20	0.84
	36	61	sex (male)	0.02±0.37	0.66	0.52
	36	61	diet*habitat	1.16±0.69	1.69	0.10
Diet on Tenericutes			intercept	5.34±0.45	-11.97	0.00
	36	61	insect diet	0.24±0.80	0.30	0.15
	36	61	seed diet	1.11±0.76	1.46	0.15
	36	61	habitat (urban)	0.01±0.74	0.02	0.99
	36	61	sex (male)	1.16±0.71	-1.63	0.12
	36	61	age (adult)	0.15±0.74	-0.20	0.84
	36	61	diet*habitat	0.84±1.53	-0.55	0.59
Diet on Actinobacteria			intercept	0.00±0.00	1.18	0.24
	36	61	insect diet	0.00±0.00	1.48	0.15
	36	61	seed diet	0.00±0.00	-0.53	0.60
	36	61	habitat (urban)	0.00±0.00	-0.14	0.89
	36	61	sex (male)	0.00±0.00	1.21	0.23
	36	61	age (adult)	0.00±0.00	1.34	0.19
	36	61	diet*habitat	0.00±0.00	1.04	0.30

Table S3. Genus-level differential abundance. P values are adjusted for False Discovery Rate (FDR). Values in dietary columns refer to mean relative abundance for each treatment.

Genus	P (FDR)	pre-dietary manipulation		post-dietary manipulation	
		insect	seed	insect	seed
Devosia	<0.001	4.24	6.48	1.93	3.06
Rickettsiella	<0.001	4.18	7.03	1.94	6.95
Cronobacter	<0.001	7.72	5.38	9.41	2.58
Rhizobium	<0.001	4.09	7.37	3.43	4.67
Sphingomonas	<0.001	6.18	7.33	3.84	6.06
Pantoea	<0.01	7.9	6.7	3.32	7.2
Arthrobacter	<0.01	7.61	6.18	4.61	5.48
Bradyrhizobium	<0.01	6.88	7.27	4.23	4.67
Microbacterium	<0.01	3.68	4.25	3.12	6.31
Lactobacillus	<0.01	9.58	9.16	11.51	10.12
Bacillus	<0.01	4.37	3.3	2.14	5.41
Staphylococcus	<0.01	10.21	9.86	7.07	9.72
Brevibacterium	<0.01	8.22	7.15	5.17	7.41
Candidatus	<0.01	3.09	2.92	6.24	4.84
Serratia	<0.01	9.48	7.74	9.28	6.2
Methylobacterium	<0.01	10.17	11.75	14.04	12.14
Ureaplasma	0.016	9.3	7.73	10.26	10.71
Brachy bacterium	0.028	7.21	5.37	4.98	5.85
Clostridium	0.032	6.02	4.44	4.36	4.02
Rahnella	0.033	9.22	8.31	7.84	6.93
Delftia	0.035	3.09	3.28	4.78	4.77
Carnobacterium	0.04	5.08	3.73	3.1	3.58

Table S4. Natural variation in the gut microbiome on Day 1.

Model	total observations	Fixed effects	$\beta \pm SE$	t-value	p
Chao1	35	intercept	18.0±0.93	19.40	<0.01
		PSP	1.32±1.59	0.83	0.41
		habitat (urban)	0.53±1.6	0.34	0.74
		sex (male)	1.20±1.55	-0.78	0.44
		age (adult)	1.65±1.54	1.07	0.29
Shannon's index		intercept	2.72±0.22	12.1	<0.01
		PSP	0.59±0.38	1.54	0.13
		habitat (urban)	0.17±0.39	0.45	0.66
		sex (male)	0.01±0.38	0.02	0.98
		age (adult)	0.20±0.37	1.09	0.28
observed species	35	intercept	0.19±0.21	44.50	<0.01
		PSP	0.19±0.21	0.91	0.37
		habitat (urban)	0.17±0.20	0.85	0.40
		sex (male)	0.10±0.20	-0.50	0.62
		age (adult)	0.18±0.20	0.87	0.39

Proteobacteria	35	intercept	-	0.37±0.56	-0.66	0.51
		PSP	-	0.40±0.76	-0.53	0.60
		age (mature)	-	1.27±0.73	1.75	0.08
		sex (male)	-	0.14±0.78	0.18	0.86
		habitat (urban)	-	0.54±0.75	-0.72	0.47
Bacteroidetes	35	intercept	-	6.97±0.44	-15.77	<0.01
		PSP	-	0.84±0.58	1.44	0.16
		habitat (urban)	-	1.01±0.55	1.82	0.08
		sex (male)	-	0.44±0.57	0.76	0.45
		age (adult)	-	0.65±0.56	1.15	0.26
Firmicutes	35	intercept	-	3.22±0.27	-11.97	<0.01
		PSP	-	0.02±0.46	0.05	0.96
		habitat (urban)	-	0.26±0.45	0.57	0.57
		sex (male)	-	0.01±0.45	0.02	0.99
		age (adult)	-	0.48±0.44	-1.07	0.29
Tenericutes	35	intercept	-	5.40±0.51	-10.60	<0.01
		PSP	-	0.26±0.87	0.30	0.77
		habitat (urban)	-	0.34±0.85	-0.40	0.69
		sex (male)	-	0.87±0.84	-1.04	0.31
		age (adult)	-	0.28±0.85	0.33	0.74
Actinobacteria	35	intercept	-	0.00±0.00	0.59	0.56
		PSP	-	0.00±0.00	-0.06	0.96
		habitat (urban)	-	0.00±0.00	2.47	0.02
		sex (male)	-	0.00±0.00	0.47	0.64
		age (adult)	-	0.00±0.00	1.95	0.06

Table S5. Beta diversity metrics for (a) natural variation (Day 1); and (b) dietary manipulation. PSP = Problem Solving Performance.

Model	Factor	Bray-curtis	Jaccard	Weighted unfrac	Unweighted unfrac
a) Natural variation (Day1)	PSP	R2=0.03, p=0.52	R2=0.03, p=0.40	R2=0.02, p = 0.57	R2=0.05, p = 0.07
	habitat	R2=0.04, p =0.07	R2=0.04, p = 0.09	R2= 0.06, p = 0.09	R2= 0.04, p = 0.09
	sex	R2=0.03, p=0.43	R2=0.03, p =0.40	R2=0.02, p =0.73	R=0.02, p =0.74
	age	R2=0.03, p=0.32	R2=0.03, p=0.30	R2=0.04, p =0.14	R=0.04, p =0.13
b) Dietary manipulation (Day 1 &12)	diet	R2=0.07, p =<0.01	R2=0.06, p <0.01	R2= 0.12, p<0.01	R2=0.07, p <0.01
	PSP	R2=0.02, p=0.09	R2=0.02, p = 1.1	R=0.01, p = 0.77	R2= 0.04, p = 0.02
	habitat	R2=0.04, p<0.01	R2=0.03, p<0.01	R2=0.05, p=0.01	R2=0.02, p=0.18
	sex	R2=0.02, p=0.31	R2=0.02, p=0.35	R2=0.02, p =0.20	R=0.01, p =0.92
	age	R=0.02, p=0.15	R2=0.02, p=0.17	R2=0.03, p =0.04	R20.02, p =0.38